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Graphene Array Based Beam-Scanning Terahertz Antenna

By
Presenter: Jibin Liu

Xianjun Huang, Ting Leng, Zhirun Hu School of Electrical and Electronic Engineering
University of Manchester Manchester M13 9PL, United Kingdom.

Jibin Liu, Zhonghao Lu, Peiguo Liu
College of Electronic Science and Engineering
National University of Defense Technology Changsha 410073, China.

Abstract: This paper presents the design of beam scanning terahertz antenna based on graphene arrays. The main lobe direction is verified to be scannable with flexibility introduced by graphene. The working principle of the beam scanning is further studied based on secondary reflection theory.

Keywords: Graphene; Beam Scanning; Flexible Antenna; THz.

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Xianjun Huang received the B.A. and M.S. degree in electrical and electronic engineering from National University of Defence Technology, China in 2011, 2013 respectively. He is currently a PhD candidate in University of Manchester , UK. His research interests include two-dimensional materials' microwave applications, printed electronics, metamaterials. He has published more than 25 peer-review journal and conference papers. His work on printed graphene RF applications was reported by Science Daily, PhysOrg, AIP Publisher, etc.

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• Abstract

This paper presents the design of beam scanning terahertz antenna based on graphene arrays. The main lobe direction is verified to be scannable with flexibility introduced by graphene. The working principle of the beam scanning is further studied based on secondary reflection theory.

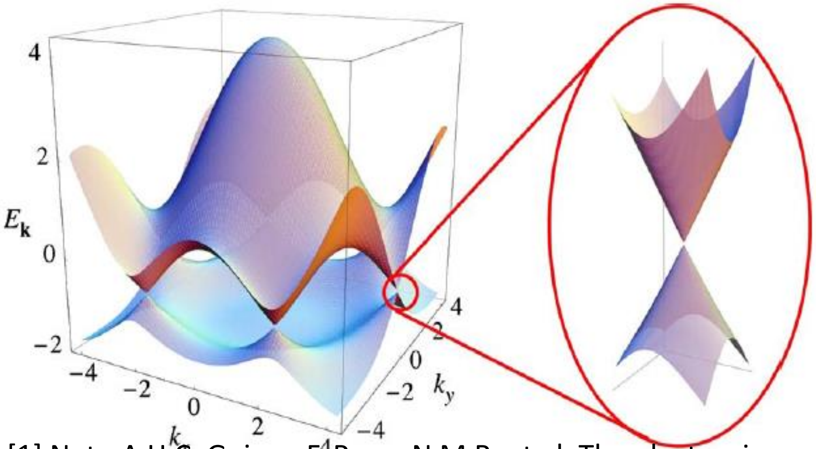
Keywords—Graphene; Beam Scanning; Flexible Antenna; THz.

• Outline

1. Introduction of Graphene and the background
2. Modelling of graphene sheet
3. Structure of graphene array based antenna
4. Results and discussions
5. Conclusions

• About Graphene

Graphene is the single atomic layer of graphite, a 2-D sheet of sp2 bonded carbon atoms arranged in a honeycomb hexagonal structure.



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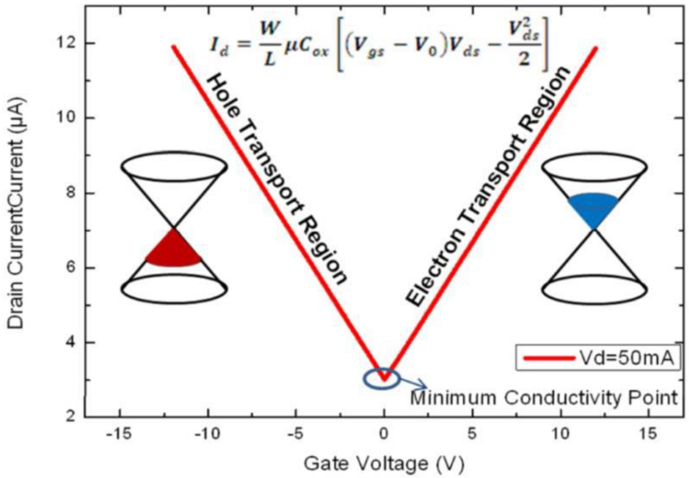

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Its unique band structure makes it a ambipolar material which its conductivity changes when its hole/electron concentration changed by applied electric field.

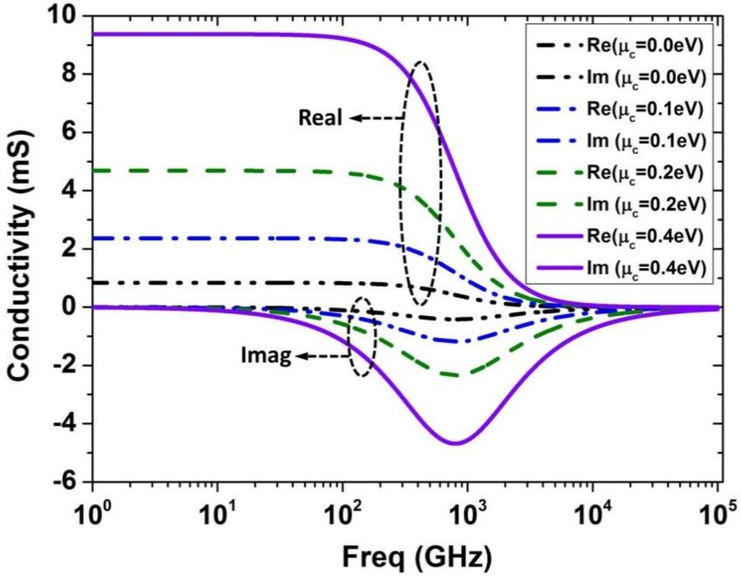
• Modelling of graphene sheet

In microwave band, according to Kobo formula, graphene is modelled with complex surface conductivity which is determined by intra-band contributions, the surface conductivity is :

$$\sigma = \frac{\sigma_0}{1 + j\omega\tau} \qquad \sigma_0 = \frac{e^2 k_B T \tau}{\pi \hbar^2} \left\{ \frac{\mu_c}{k_B T} + 2\ln\left(e^{-\mu_c / k_B T} + 1 \right) \right\}$$

where e is the electron charge, $\hbar$ is the reduced Planck's constant, is Boltzmann's constant. μc is the chemical potential, T is the temperature, ω is the operation frequency and τ is the electro-phonon relaxation time. Here the temperature is assumed to be 300K, and τ=0.2ps.

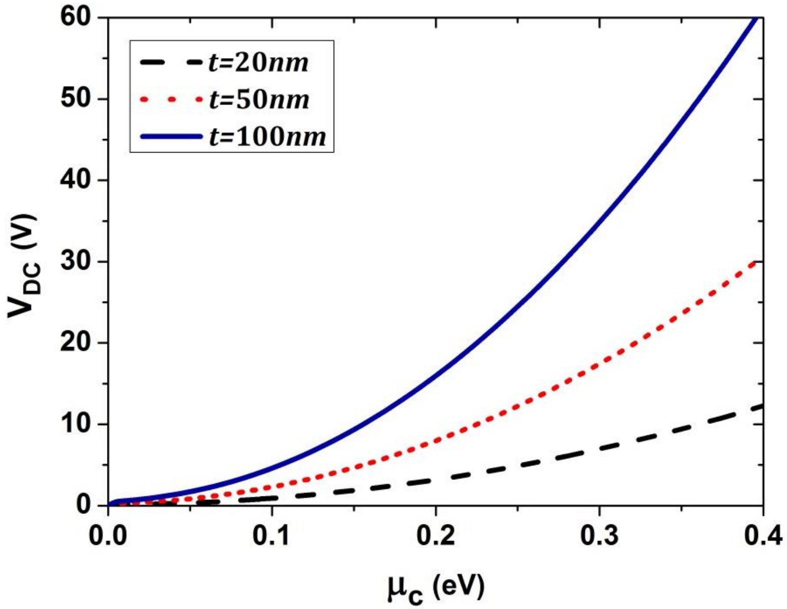
The complex surface conductivity of graphene calculated



• Modelling of graphene sheet

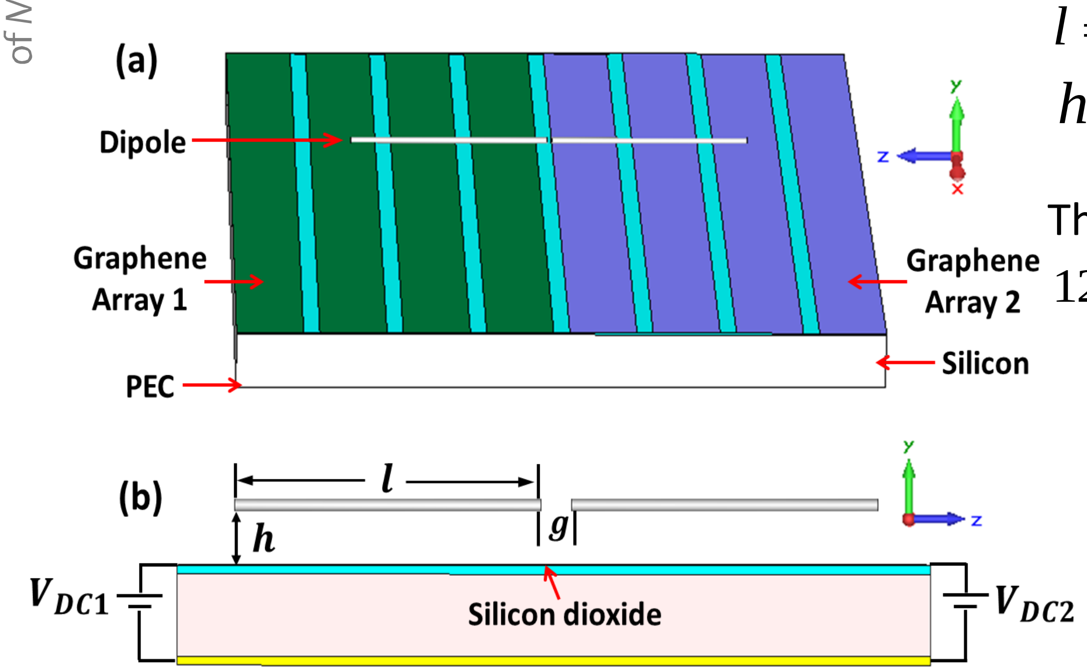
The complex conductivity of graphene changes dynamically with chemical potentials. The corresponding surface impedance of graphene sheet can be calculated with:

$$Z_s = \frac{1}{\sigma} = \frac{1 + j\omega\tau}{\sigma_0}.$$



Relationship between chemical potential of graphene and external voltage under different isolation layer thickness.

• Structure of graphene array based antenna


(a)
Dipole
Graphene Array 1
Graphene Array 2
Silicon
PEC
y
z
x
(b)
l
h
g
V_{DC1}
V_{DC2}
Silicon dioxide
y
z

$l = 37um \quad g = 0.75um$

$h = 9um$

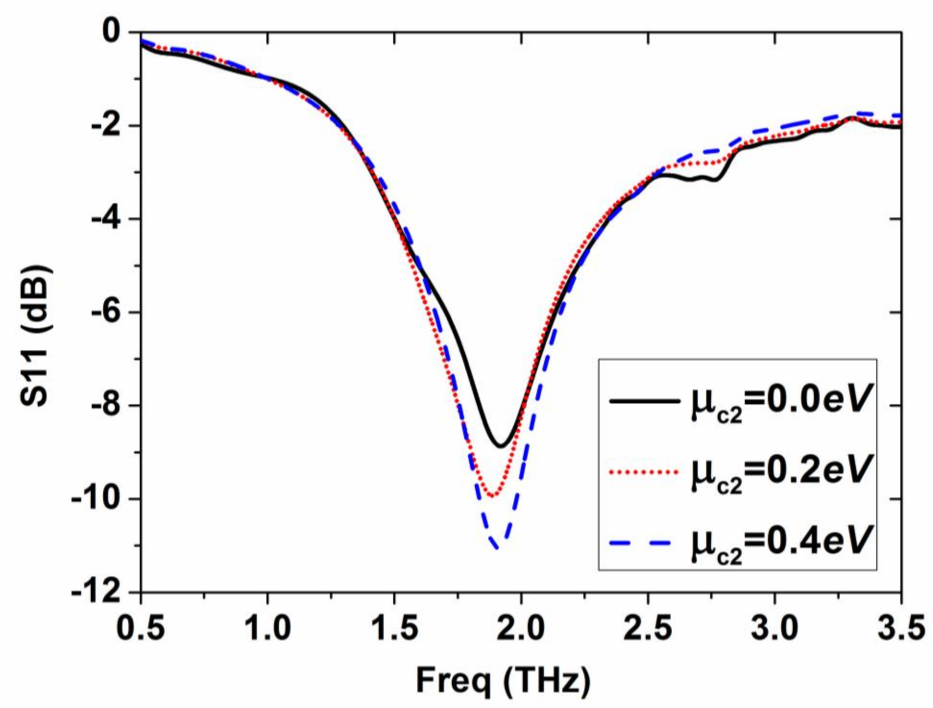
The size of graphene strips is $120um \times 12.4um$

a straight dipole antenna is placed above graphene strips array, and graphene array strips are divided into two groups as graphene array 1 and graphene array 2.

The arrays are connected external voltage VDC1 and VDC2 separately to tune the chemical potential. To facilitate the tunability of graphene, an ultrathin layer of silicon dioxide with thickness t is placed between graphene layer and doped silicon.

• Results and discussions

Reflection of the antenna with different μ_{c2}

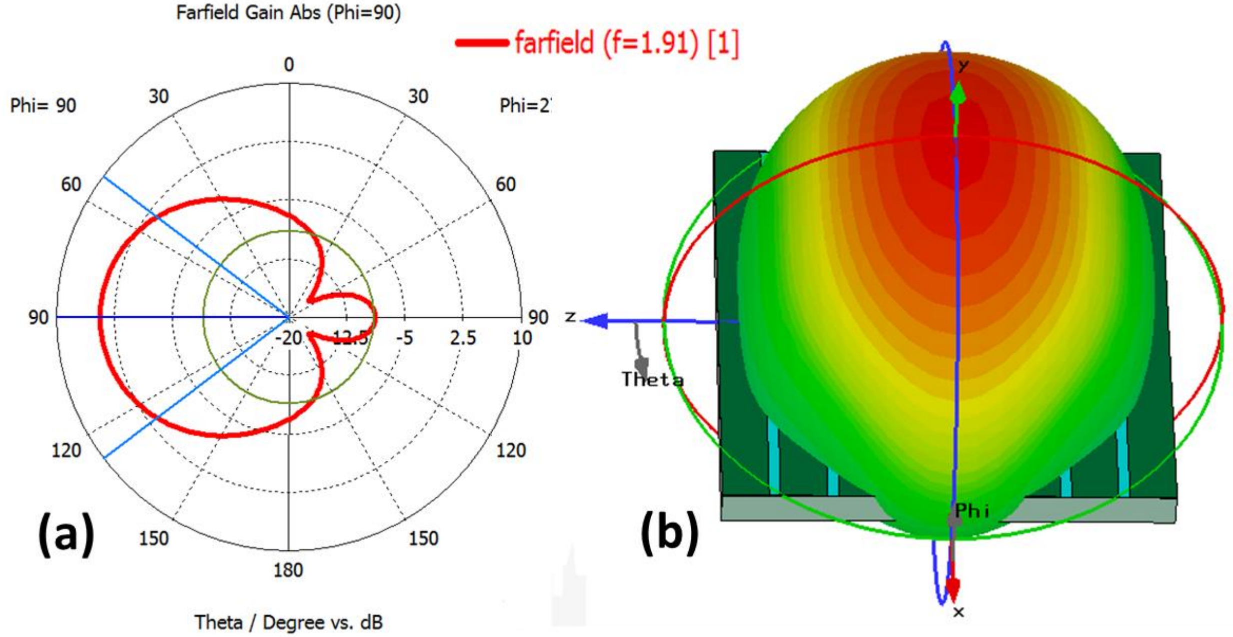


When array 1 is with μc1=0eV, namely VDC1 =0V, and apply VDC2 to tune graphene in array 2 to different chemical potentials

The working frequency is 1.91THz, at which the dipole is half-wavelength. The working frequency under different μc2 is hardly changed, namely the resonance frequency mainly determined by straight dipole dimensions.

• Results and discussions

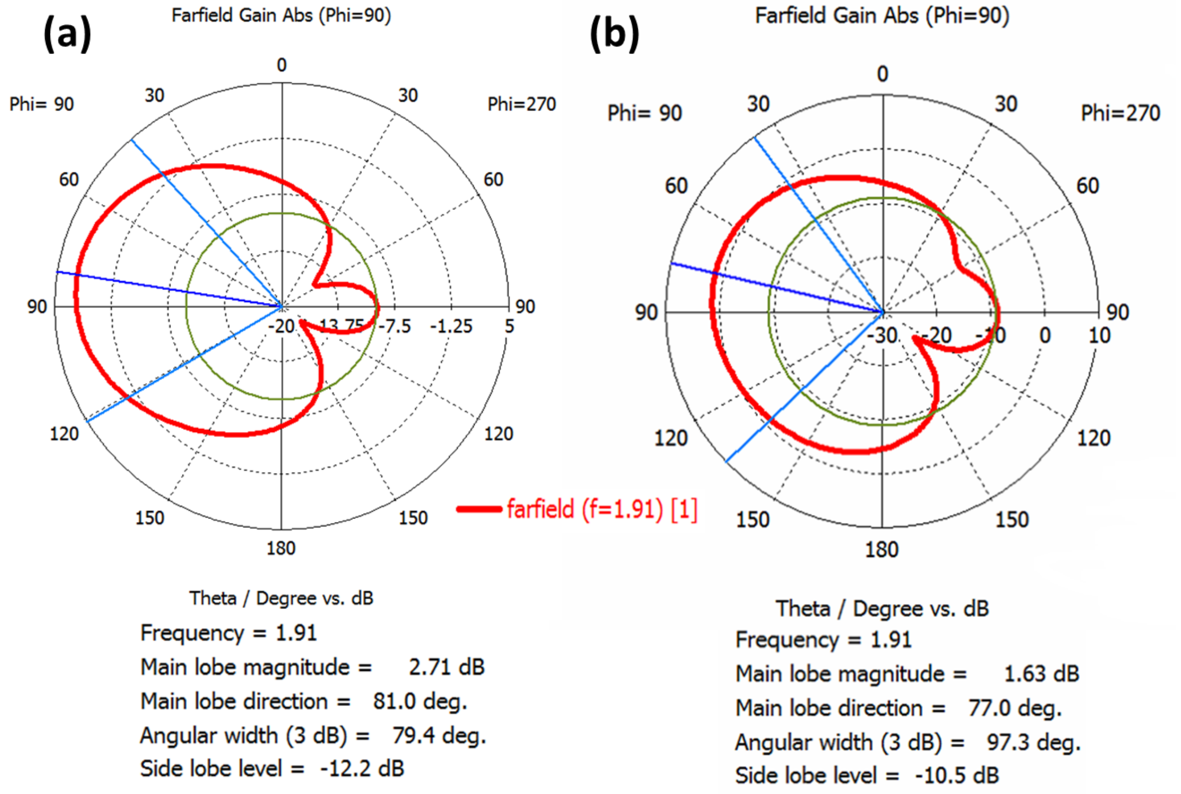
Beam scanning performance



When the external voltages of two graphene arrays are the same with VDC1 = VDC2 =0V, the 3D radiation pattern of antenna is shown. It is a typical radiation of dipole antenna with backed PEC, and the main lobe direction is in Y axis.

Results and discussions

Beam scanning performance



(a)

Theta / Degree vs. dB
Frequency = 1.91
Main lobe magnitude = 2.71 dB
Main lobe direction = 81.0 deg.
Angular width (3 dB) = 79.4 deg.
Side lobe level = -12.2 dB

(b)

Theta / Degree vs. dB
Frequency = 1.91
Main lobe magnitude = 1.63 dB
Main lobe direction = 77.0 deg.
Angular width (3 dB) = 97.3 deg.
Side lobe level = -10.5 dB

when μ_{c2}=0eV, the main lobe direction is at theta=90, which means Y direction. When tuned to μ_{c2}=0.2eV, 0.4eV separately, the main lobes are at theta=81 and 77 degree, which mean main lobe rotation of 9 degree and 13 degree respectively.

• Results and discussions

Principle of Beam scanning performance

The dipole antenna here is the source antenna, which is the reason why working frequency is hardly affected.

The graphene array and PEC backed dielectrics works as secondary reflection array, the radiation is the addition of dipole radiation and secondary radiation.

However, the secondary radiation is not symmetrical because of the different external voltage added (which changes graphene’s complex surface conductivity), making the current on graphene array unsymmetrical, and main lobe direction rotated away form 90 degree.

• Conclusions

- Graphene array here introduces flexibility to the antenna, and the main lobe of radiation is demonstrated to be scannable with external voltages applied to graphene array.

- The rotation of radiation pattern demonstrates that the introduction of graphene array here make the antenna flexible and enabled with beam scanning characters.

- The beam scanning angle is expected to be further enhanced if the antenna above graphene has narrow main lobe.

Many Thanks for your attention!
Any quesitions?

Xianjun Huang, Ting Leng, Zhirun Hu
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University of Manchester
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